Patient-Controlled Analgesia

A New Concept of Postoperative Pain Relief

RICHARD L. BENNETT, M.D.,* RANDY L. BATENHORST, PHARM. D.,† BRACK A. BIVINS, M.D.,‡
RICHARD M. BELL, M.D.,‡ DAVID A. GRAVES, PHARM. D.,† THOMAS S. FOSTER, PHARM. D.,†
BALLARD D. WRIGHT, M.D.,* WARD O. GRIFFEN, JR., M.D., PHD.‡

This report concerns evaluation of patient-controlled analgesia (PCA) in the form of two preliminary investigations. In the first study, the patient-controlled analgesia device, which consists of a pump linked to a timer so that patients can activate intravenous administration of morphine sulfate to themselves during the postoperative period, was used in seven morbidly obese patients. The amount of morphine used during the first 36 hours was found to vary between 32 and 185 mg, with a significant difference in drug usage when related to weight as well as to body surface area. In the second study, morbidly obese patients undergoing gastric bypass operations were prospectively randomized into 12 patients who used the PCA device in the postoperative period and 12 patients who were given standard intramuscular dosages of morphine sulfate. An analgesia and sedation scale was then used to compare the two groups. The patients in the PCA group were able to maintain a state of adequate analgesia without sleep with a significantly greater frequency than were those in the intramuscular injection group. On the basis of answers to a questionnaire given to the patient after 60 hours of morphine analgesia, it was apparent that the PCA group was much more satisfied with that form of postoperative analgesia. It would appear that PCA is an efficacious and safe method of providing for postoperative pain relief.

From the Departments of Anesthesia and Surgery of the College of Medicine and the Division of Clinical Pharmacy of the College of Pharmacy, University of Kentucky, Lexington, Kentucky

OFTEN, PATIENTS may fear an operation more for the prospect of pain than for the mortal risks of the procedure.[1] Fear of pain, although intangible and subjective, may mature from the child's question "will it hurt?" to the adult's procrastination in seeking medical care. Postoperative pain may interfere with early ambulation, pulmonary toilet, and other patient activities helpful to early recovery. There is a wide variety of medications available to combat pain, but unfortunately none when administered as a large bolus dose achieves the ideal of eliminating pain without untoward side effects. The most effective agents for pain control, of course, are the narcotic analgesics, which have a number of risks, including respiratory depression.[2] In practice, adequate pain control represents the compromise sought between severe pain and respiratory depression with complete analgesia. This usually involves the administration of a "standard" dose of a narcotic analgesic intramuscularly on a time sequence basis, with little regard for the patient's pain threshold or body habitus.

The authors' experience with operative procedures in a large number of morbidly obese patients over the past eight years had reinforced the importance of body size on the dosing of analgesics, as well as of other drugs.[3-5] Clinical observation suggested that although the overall analgesia requirement was higher for the morbidly obese patient than for more normally sized patients, there was still a wide range in narcotic dosages needed for adequate analgesia. This led to a prospective study of analgesic requirements in the morbidly obese, in an attempt to relate narcotic effective dose to a parameter related to size, such as weight or body surface area. In that pilot study, a device that allowed the patient to self-administer the prescribed narcotic dose within rigidly controlled limits was used in an attempt to determine optimum analgesic dosing. Success with the concept and technology of patient-controlled analgesia (PCA) in the first study led to a second larger study comparing self-administered narcotic dosing (PCA) with the traditional time-sequence, fixed dosing of narcotic. This is a report of those two studies.

Presented at the Annual Meeting of the Southern Surgical Association, December 7-9, 1981, Hot Springs, Virginia.

* Department of Anesthesia.
† Division of Hospital Pharmacy.
‡ Department of Surgery.
Reprint requests: Ward O. Griffen, Jr., M.D., Ph.D., Department of Surgery, University of Kentucky Medical Center, 800 Rose Street, Lexington, KY 40536.

Submitted for publication: December 23, 1981.

0003-4932/82/0600/0700 $00.85 © J. B. Lippincott Company

The patients
University of I
gastric bypass
All patients we
body weight, as
into the studies
were nonsmoke
or drug use; 3)
concurrent illne
the studies by
entered into St
narcotic analge
patients were e
controlled anal
sequence analg

All patients
gastric bypass
imal gastric po
nostomy.[6] This
upper abdomir
medication for
phine sulfate,
25 mg/M²BSA
Minor dosage
of convenience
duced with in
maintained
Pancuronium
during the ope
of the procedu
After operatio
gesia, with ro
according to t
jected as the pe
of sedative pre

Patient-cont
infusion pump
vice. The pati
thumb button
from the mach
triggered, the
ication into ar
is programmec
until a specific
terval prevents

In these stu
manalg Enterp
a Sage 351 inf
used (devices
other manufac

§ Pye Dynamic
ceutica, Inc., Bur

Materials

The patients in both studies were admitted to the University of Kentucky Medical Center for elective gastric bypass in the management of morbid obesity. All patients were a minimum of 50 kg over their ideal body weight, as determined by actuarial tables. Entry into the studies was restricted to those patients who: 1) were nonsmokers; 2) had no history of chronic analgesic or drug use; 3) were not heavy drinkers; 4) had no major concurrent illness; and 5) would agree to participate in the studies by informed consent. Seven patients were entered into Study I to determine optimum dosing of narcotic analgesics in the morbidly obese. Twenty-four patients were entered into Study II, in which patient-controlled analgesia was compared with standard time-sequence analgesia.

All patients in both studies underwent a standard gastric bypass procedure with creation of a 30-ml proximal gastric pouch and 10-mm Roux-en-Y gastrojejunostomy.[6] This procedure is carried out through a long upper abdominal transverse incision. Anesthetic premedication for all patients included intramuscular morphine sulfate, 0.5 mg/M²BSA; hydroxyzine pamoate, 25 mg/M²BSA; and glycopyrrolate, 0.2 mg/M²BSA. Minor dosage adjustments were made for the purpose of convenience of administration. Anesthesia was induced with intravenous sodium pentothal, and was maintained with inhalation enflurane and nitrous oxide. Pancuronium bromide was used for muscle relaxation during the operation, and was reversed at completion of the procedure with neostigmine and glycopyrrolate. After operation, morphine sulfate was used for analgesia, with route of administration and dose varying according to the study group. Benzquinamide was selected as the postoperative antiemetic because of its lack of sedative properties.

Patient-controlled analgesia equipment consists of an infusion pump electronically connected to a timing device. The patient triggers the device by depressing a thumb button conveniently located on a cord extending from the machine (similar to a nurse call button). When triggered, the machine delivers a preset amount of medication into an indwelling intravenous line. The timer is programmed to preclude additional medication doses until a specified time has elapsed. This "lock-out" interval prevents overdosage with the narcotic agent.

In these studies, a Demanalg II timing device (Demanalg Enterprises, Ltd., Ontario, Canada) in line with a Sage 351 infusion pump (Demanalg Enterprises) was used (devices with similar functions are available from other manufacturers§). The pump syringe line was connected to the patient's indwelling intravenous line at the injection port nearest the patient. Patients were instructed in the use of the device at the time informed consent was obtained.

§ Pye Dynamics, Bushey, Herts, Great Britain; Janssen Pharmaceutica, Inc., Burse, Belgium.

Methods

Study I

Seven consecutive patients were studied utilizing the patient-controlled analgesia equipment in an attempt to determine optimal narcotic dosing. Patients were allowed to begin using the analgesic administration device upon emergence from anesthesia in the recovery room and were returned to the ward with the device in place upon meeting routine recovery room criteria. Successful triggering of the device administered a bolus dose of narcotic over a period of 15 seconds. The initial dose setting was 0.6 mg of morphine sulfate/M²BSA. A "lock-out interval" of six minutes was interposed between injections by the timing unit. An optimal analgesic dose of narcotic was defined as that dose that produced appreciable analgesia without producing subjective sedation. Adjustments in dose in increments of 0.2 mg morphine sulfate/M²BSA were made when necessary to achieve that analgesia criterion. The device was used for 60 hours after operation; the patient was then switched to a standard intramuscular narcotic regimen.

Study II

This study was designed as a prospective randomized comparative trial of patient-controlled analgesia (PCA) and traditional time-sequence, fixed-dose intramuscularly administered analgesia (IM). Twenty-four consecutive study patients were assigned by a computer-generated randomization scheme to either the PCA group or the IM group. The 12 patients in the PCA group received intravenous narcotic via the self-administration device according to the same protocol outlined in Study I. The 12 patients randomized to the IM group received a traditional time-sequence narcotic regimen of morphine sulfate: 8–12 mg administered intramuscularly every four to six hours as needed.

The nursing staff recorded narcotic usage and analgesia sedation status every two hours from 10:00 P.M. the night of surgery until 6:00 A.M. of the third postoperative day. The level of analgesia was rated on a scale of 1 to 3, ranging from patient evaluation of "comfortable" to "in pain"; sedation status was rated on a scale of 1 to 4, with observations ranging from "wide awake" to "mostly sleeping" (Table 1). A questionnaire evaluating subjective perceptions of postoperative pain was reviewed by one of the authors (RLB) with each of the study patients on the morning of the third postoperative day (Fig. 1).

TABLE I. *Analgesia and Sedation Rating Scales*

Analgesia scale
1. "comfortable"
2. "in mild discomfort"
3. "in pain"
Sedation scale
1. "wide awake"
2. "drowsy"
3. "dozing intermittently"
4. "mostly sleeping"

Results

Study I

The postoperative course was uneventful in all seven patients, and all considered the self-administered analgesia to be satisfactory. On the third postoperative day, all seven patients characterized their postoperative course as "comfortable" or "mildly uncomfortable." The mean total dose of morphine sulfate used by these patients during the 60-hour study period was 107 mg, or an average of 1.8 mg per hour. The greatest use of narcotic occurred in the first 36 hours after operation. The demand for narcotic varied widely from patient to patient during the initial 36 hours, ranging from 32 to 185 mg. This range remained more than fivefold when related to weight (0.33–1.74 mg/kg) and body surface area (16.4–90.2 mg/M²).

Study II

Postoperative courses for the 24 patients in this study were uniformly uneventful. The data from the two groups of patients were analyzed using the Mann-Whitney U form of the Wilcoxon Rank Sum test.

FIG. 1. Study questionnaire.

1. On the whole, how would you describe how you've felt since the operation:
   a) comfortable
   b) mildy uncomfortable
   c) very uncomfortable
   d) in pain
   e) in bad pain
2. Except for the day of the operation itself, which of the following best describes how sleepy you've felt since the operation during the daytime:
   a) wide awake
   b) slightly drowsy
   c) moderately drowsy
   d) very drowsy
3. Do you feel that getting a dose of pain medication made you:
   a) more active
   b) less active
   c) can't tell
4. (PCA-group patients only) As compared with other methods of pain relief, would you:
   a) *much* rather have patient-controlled analgesia after a future surgery
   b) rather have patient-controlled analgesia after a future surgery
   c) not care which type of pain relief method you receive in the future
   d) rather have a regular pain treatment method after a future surgery

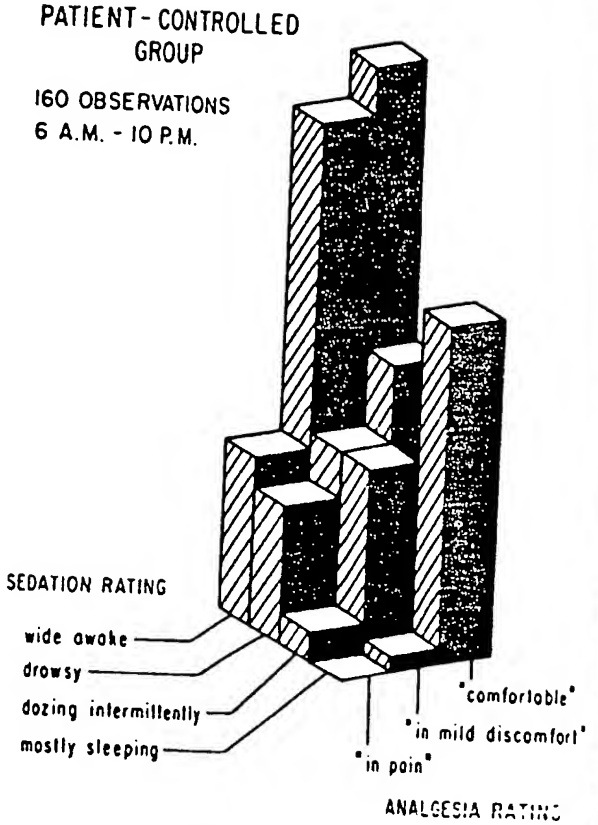

FIG. 2. Compiled concurrent analgesia and sedation ratings in PCA patients.

The analgesia and sedation ratings during "normal waking hours" (6:00 A.M. to 10:00 P.M.) were analyzed (Figs. 2 and 3). Patients in the PCA group were able to maintain a state of adequate analgesia without sleep (*i.e.*, "comfortable" or "in mild discomfort" while "wide awake" or "drowsy") with a greater frequency than were patients in the IM group (59 *vs.* 40%, 309 total observations, $p < 0.01$). Patients reported inadequate analgesia ("in pain") more frequently in the IM group (22 *vs.* 14%, p = NS).

Patients in the IM group were noted to exhibit more sedation between 6:00 A.M. and 10:00 P.M. than did patients in the PCA group. Patients in the IM group were charted as "dozing intermittently" or "mostly sleeping" in 48% of chartings, as opposed to 28% of chartings in the PCA group (p = NS).

Sedation ratings (231 total) indicated greater sedation in the PCA group than in the IM group during "normal sleeping hours" (10:00 P.M. to 6:00 A.M.), but the difference was not statistically significant. Patients in the PCA group were noted to be "dozing intermittently" or "mostly sleeping" in 74% of the observations;

Patients in
of their cha
two groups
in the PCA
as often as
= NS).

Differenc
by question
Analgesia,
greater in tl
(92%) patie
postoperativ
fortable," w
IM group c
favorably. I
two groups
the nursing
characterize
tients ($p <$ (
group "widc
with 17% of

Finally, th
assessed by
with physic
the PCA ro
the patients
them "less a
in the PCA

Many pers
because of p
that are usu
Moreover, n
between thei
tration of th
periencing m
may be grea
in order to a

There is
differ in the
study I subst
variation ma
nomenon, wh
tolerant to p
enon, whereb
larger persor
supported by
accurately th
gested that
most efficien
would seem t
effective and

Patients in the IM group received these ratings in 65% of their chartings. Analgesia ratings also differed in the two groups between 10:00 P.M. and 6:00 A.M. Patients in the PCA group reported "pain" less than one third as often as patients in the IM group (3.9 *vs.* 11.8%, p = NS).

Differences between the two groups, as determined by questionnaire, confirmed the nursing observations. Analgesia, as assessed by questionnaire, was again greater in the PCA group ($p < 0.05$). Eleven of the 12 (92%) patients in the PCA group characterized their postoperative state as "comfortable" or "mildly uncomfortable," while seven of the 12 (58%) patients in the IM group characterized their net analgesic state this favorably. Daytime sedation status differences in the two groups indicated by questionnaire also supported the nursing chart observations. Overall, PCA patients characterized themselves as less sedated than IM patients ($p < 0.05$), with 50% of the patients in the PCA group "wide awake" or "slightly drowsy," compared with 17% of the IM group.

Finally, the effect of pain medication on activity level, assessed by questionnaire, indicated less interference with physical activity by medication administered by the PCA route ($p < 0.001$). In the IM group, 83% of the patients stated that their pain medication made them "less active," as opposed to only 8% of patients in the PCA group who responded in this manner.

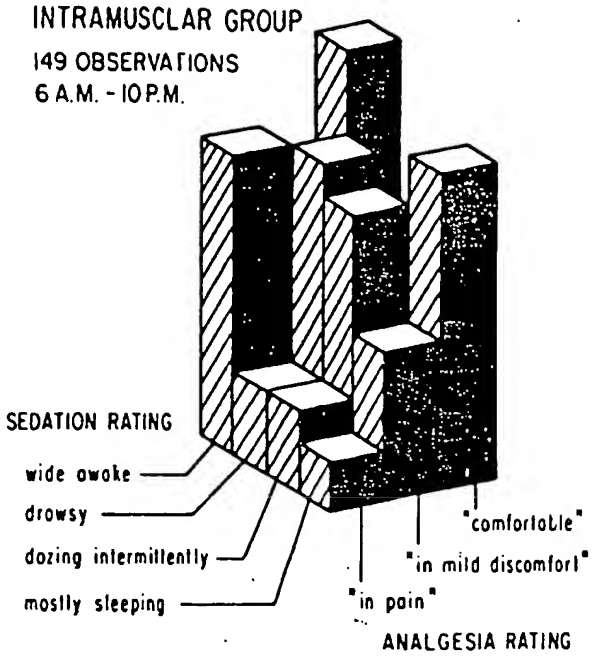

FIG. 3. Compiled concurrent analgesia and sedation ratings in the IM group.

Discussion

Many persons are concerned about an operation more because of postoperative pain than because of the risks that are usually discussed in detail by the surgeon. Moreover, many patients describe a substantial delay between their request for pain relief and the administration of the analgesic. Thus, the patient who is experiencing mild pain will accept a dose of narcotic that may be greater than that required to relieve the pain in order to avoid experiencing severe discomfort.

There is now increasing evidence that individuals differ in their pain-relief requirements. The data in study I substantiate the wide individual variations. This variation may be on the basis of a pain-threshold phenomenon, whereby an individual is simply more or less tolerant to pain, or it could be a dose-to-size phenomenon, whereby more analgesia may be required for a larger person. However, the latter explanation is *not* supported by the data in study I. The inability to predict accurately the individual analgesic requirement suggested that a self-administration system may be the most efficient means of achieving analgesic effect. It would seem that the PCA is such a system, being both effective and safe.

Once it has been established that there are individual variations in postoperative analgesia requirements, there then remains the question of adequate analgesia *versus* sedation. This area is admittedly subjective but very important. It also affects the nurses' interactions with the patient. Obviously, if patients feel too much pain, they will be demanding and perhaps uncooperative. In contrast, if patients receive too much postoperative analgesia, they will be unable to perform tasks requested by the nurse. In this event, patients may also fail to clear their lungs sufficiently or have interference with bowel motility, both of which could delay recovery. Study II clearly establishes that adequate analgesia was achieved more often by PCA than by conventional administration of the analgesic. Similarly, sedation appeared to be more appropriate in patients in the PCA group than in the IM group.

In both study groups, there were three patients who had undergone at least one abdominal procedure before the gastric bypass. They were asked to compare PCA with conventional intermittent injections for analgesic effect. All stated that PCA was far superior to intermittent dosing techniques. The reasons given for the superiority are important: 1) there is no delay between perception of pain and administration of analgesia; 2) there is no feeling of helplessness because of too much analgesia; and 3) the patient, not the doctor or nurse, controls the use of the analgesic.

In 1680, Sydenham wrote: "Among the remedies which it has pleased Almighty God to give to man to relieve his sufferings, none is so universal and so efficacious as opium".[7] Now it is possible for each person to control the amount of "opium" given in order to achieve optimum pain relief while remaining aware of the environment.

References

1. Cronin M, Redfern PA, Utting JE. Psychometry and postoperative complaints in surgical patients. Br J Anaesth 1973; 45: 879.
2. Jaffee JH, Martin WR. Narcotic analgesics and antagonists. In: Goodman LS, Gilman A, eds. The Pharmacologic Basis of Therapeutics. New York: MacMillan, 1975; 245.
3. Tseuda K, DeBrand M, Bivins BA, et al. Pulmonary complications in the morbidly obese following jejunoileal bypass surgery under narcotic anesthesia. Int Surg 1980; 65:123.
4. Bauer LA, Blouin RA, Griffen WO, et al. Amikacin pharmacokinetics in morbidly obese patients. Am J Hosp Pharm 1980; 37:519.
5. Dione RE, Bauer LA, Gibson GA, et al. Estimating creatinine clearance in morbidly obese patients. Am J Hosp Pharm 1981; 38:841.
6. Bivins BA, Griffen WO, Steichen FM. Surgical procedures on the small intestine. In: Schwartz SI, ed. Modern Techniques in Surgery. New York: Futura 1981; 1-44.
7. Latham RG. The Works of Thomas Syndenham. London: The Syndenham Society, 1893.

Discussion

Dr. Henry L. Laws (Birmingham, Alabama): We, too, have been interested in postoperative pain relief. My colleague, Dr. Simon Gelman, studied postoperative pain in 38 of our morbidly obese patients. For pain relief, 17 patients received intravenous morphine in 2-mg increments. Most received about 6 mg for adequate analgesia. Twenty-one patients received morphine via a high thoracic epidural catheter. We anticipated improved respiratory function and, perhaps, better analgesia, with the epidural injections.

Such was not the case. Pain relief in both groups provided adequate gas exchange and the same degree of vital capacity restoration.

The morphine group developed an increased oxygen consumption with pain after operation, and a decrease in oxygen consumption with analgesia. The epidural patients also had some decrease in oxygen consumption with analgesia. Patients receiving thoracic epidural anesthesia experienced somewhat sharper decreases in cardiac index, left ventricular stroke work, in the heart rate-system blood pressure product, with no changes in blood gas tension or actual bicarbonate, and a decrease in the arterial venous oxygen content difference, suggesting a decrease in the total oxygen requirement.

(slide) This shows the heart rate-systemic arterial pressure product in patients receiving morphine and epidural anesthesia; indeed, both pain-relieving methods afforded relief, as you can see, with the injection.

However, the epidural patients complained a great deal more about discomfitures remote from the incision, while morphine anesthesia appeared to aid in making these more tolerable. For instance, a nasogastric tube seems intolerable if you don't have an incision that's hurting.

I would like to ask the authors if they anticipate the use of this technique on selected patients only, or on all patients in the future, and whether they used this technique on the surgical ward or just in the intensive care unit.

Dr. R. L. Bennett (Closing discussion): Patient-controlled analgesia, or "PCA," works so very well because narcotic analgesics are such good drugs. These drugs have the unique ability to relieve pain, virtually regardless of severity, without producing untoward effects, sedation and respiratory depression. To produce analgesia without sedation, however, drug dosing must be individualized and carefully titrated.

PCA allows one to make available to patients continuous, immediate access to whatever amount of analgesic they need. Patients trigger the device upon the perception of pain, receiving a small (about 1 mg morphine), intravenous dose of analgesic. They are instructed to maintain analgesia without sedation. Patients do indeed maintain an appropriate, well-titrated level of analgesic when using this technique. Provision of pain relief to patients without sedation is of itself worthwhile. We are starting to see physical benefits of this therapy, as well.

We have recently completed a report documenting the efficacy of narcotic titration with PCA. (slide) This report concerns 50 patients using PCA for postoperative analgesia following elective laparotomy. Patients used the machine an average of 60 hours after operation (3,018 hours total). Concurrent analgesia and sedation rankings were performed by the ward nursing staff every two hours. Charting was performed during the "normal waking hours" of 6 AM to 10 PM. Seven hundred seven nursing chartings are reported. The large majority of observations were of patients in either the categories "comfortable" or "mildly uncomfortable." Also, the majority of sedation observations were "wide awake." In only 6.5% of the observations did patients admit any pain, and only 1.1% of the time did they have pain that they categorized as "bad" pain. We only had one report of "very bad pain." This event occurred during a disruption of the system, intravenous line infiltration.

Patients were asleep in 8% of the chartings in this study. Some degree of increased somnolence is to be expected in recovery from major surgery. Our respiratory rate observations argue against a predominant narcotic-induced component in this sleep.

The mechanism of toxicity of narcotic analgesics is a dose-related decrease in minute volume, which is effected by a dose-related decrease in respiratory rate. Tidal volume is maintained at, or even increased above, predose levels. One normally does not suspect narcotic-induced respiratory depression with respiratory rates greater than 10. In this same study, the nursing staff made respiratory rate observations every two hours around the clock on the study patients. (slide) A total of 1,333 respiratory rates were recorded. In only 1.2% of these chartings did the patient have respiratory rates less than 16. The lowest rate in the entire study was a value of 12 per minute.

Our comparative PCA and intramuscular dosing study documents that the appropriate analgesic titration seen with PCA is indeed superior to that obtained with intramuscular dosing.

The adverse sequelae of intramuscular analgesic dosing are indeed multiple. Intramuscular dosing produces wide swings in serum blood concentrations. As a result, patients spend much of the time overdosed, with resultant sedation and respiratory depression; they have decreased sighing rates, which predisposes them to atelectasis; and their activity level and cooperation with therapy are decreased.

Intramuscularly dosed patients are also much of the time underdosed or in pain. They are, again, relatively inactive at these times. Sympathetic overactivity is typically present in patients with pain. This has adverse effects on the cardiovascular system in patients with coronary artery disease. It also shuts down blood flow and neural activity to the gut, which may prolong GI recovery. We are, in fact, seeing in a comparative study—and I think we will have statistical significance before long—that bowel recovery is enhanced by maintenance of properly titrated analgesic with the PCA techniques.

We have already established that pulmonary recovery is enhanced in PCA-treated patients. We are measuring preoperative and postoperative forced vital capacity and peak flow in our comparative study with Dr. Griffen's gastric bypass patients. (slide) Analysis of the outcome in our first 20 patients reveals less impairment in PCA-treated patients in both tests. The results for peak flow are already statistically significant at this early stage of our investigation.

Dr. Phillip Brommage of Duke University has done similar comparisons of intramuscular narcotic and thoracic epidural analgesia, and he obtained results similar to ours. Perhaps the point here is that intramuscular dosing is a very poor technique for administering narcotic analgesics.

We have used this device almost exclusively in a ward setting. By design, PCA devices are quite safe. No complications have been reported from the therapy by any investigator. The technique is well accepted by the ward nurses. It appears to have a considerable nursing manpower-sparing attribute. With widespread use, our nurses estimate that PCA could save them one to two hours per shift in medication-administration time. We are currently planning a study to examine this formally.

We think that PCA deserves to become a very widely employed drug-administration strategy. I think that any patient requiring more than one or two parenteral analgesic doses in the postoperative period would benefit from this form of drug administration.

PCA was described in 1967. The vast majority of the literature thus far, however, has been in the anesthesia literature. The patient population involved is the postoperative surgical patient population. Surgeons, not anesthesiologists, are the primary physicians of these patients. This therapy, thus, seems to be more in the domain of surgery than in that of anesthesiology. Widespread use of the technique will be dependent on the initiative and efforts of surgeons.

A major American medical technology corporation is currently testing the first PCA device that is truly suited for convenient ward use. The device should be commercially available within one year. It is certainly our hope that this will precipitate fast dissemination of the therapy. I totally avail myself to you in any efforts to initiate this therapy in your home institutions.